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(54) Improvements in and relating to breathing apparatus

(57) A self-rescue breathing apparatus having a combined cylinder-head and first-stage pressure-reducing valve 2 and a demand valve 5. The pressure-reducing valve 2 has a piston 31 and valve member 24 opposed to one another so that the inlet port 22 is within the valve cylinder 21 and only a single pressure seal 32, round the piston head 31 is needed. The cylinder head valve 2 also has means 14 to 20 for recharging the gas cylinder 1 without removing the gas cylinder from the apparatus or the valve 2 from the gas cylinder. The demand valve 5 is a negative-pressure diaphragm valve with a combined spring and valve lever 63 holding the valve shut against the supply pressure and a second lever 73 engaging the diaphragm 60 and lifting the first lever 63. The two-lever mechanism gives a compact and easily-adjusted valve mechanism. The apparatus also has a breathing bag (10, Fig. 5, not shown) folded, rolled up and stored in an end cap (9, Fig. 1, not shown) when not in use.

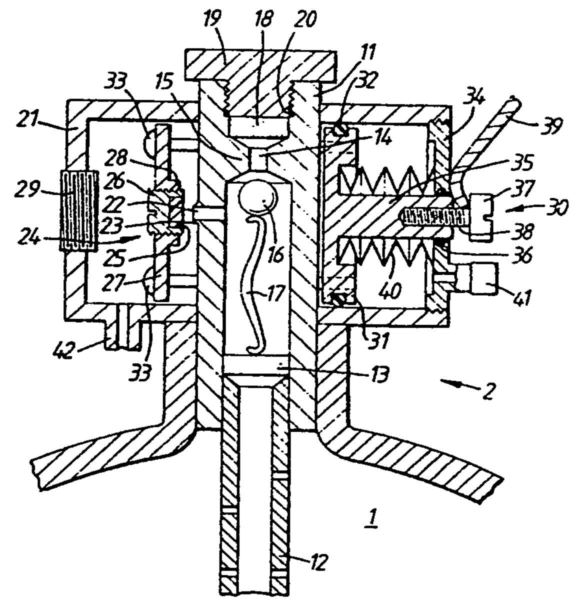

FIG. 2.

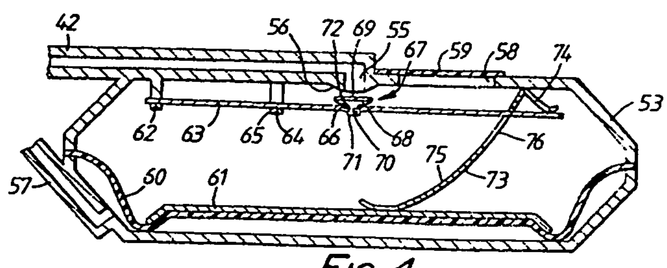

FIG. 4.

The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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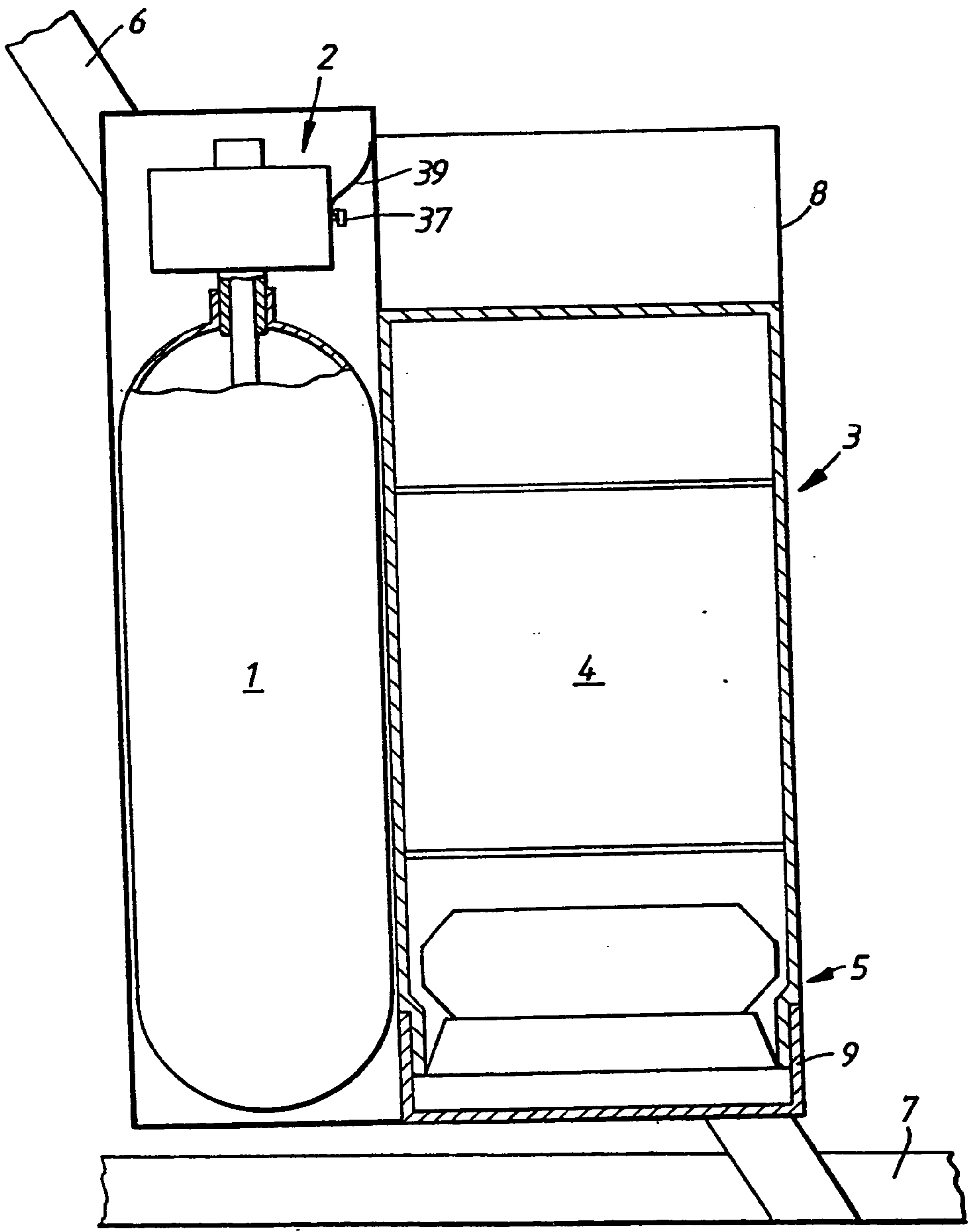

FIG.1.

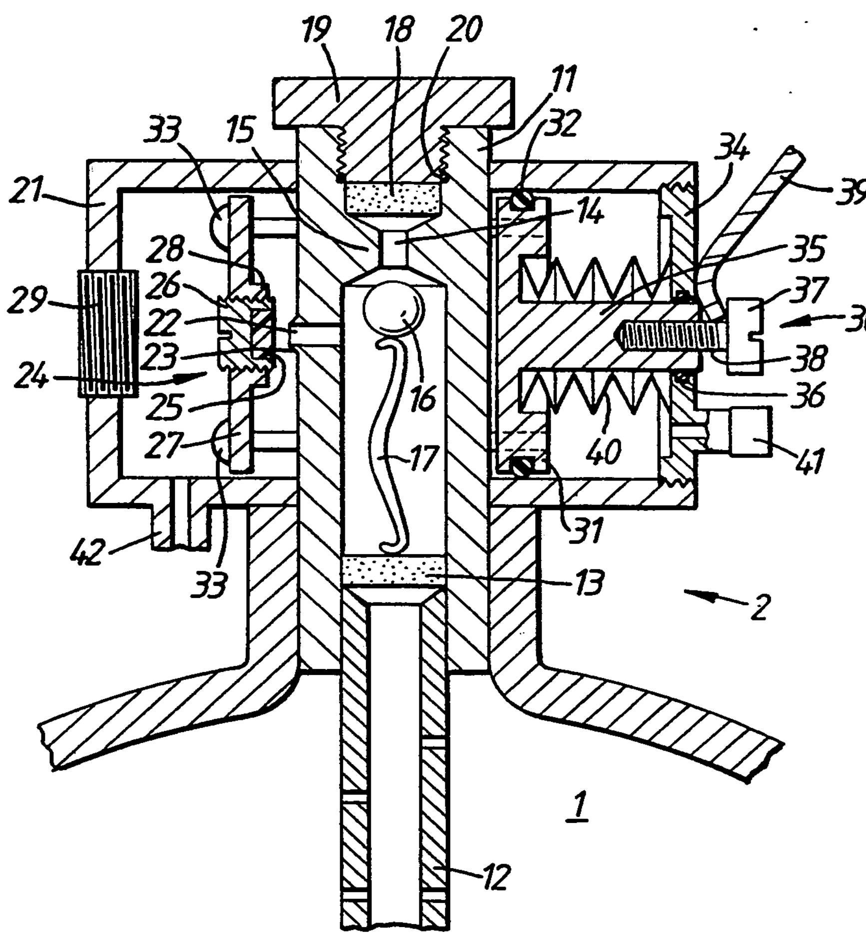
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FIG. 2.

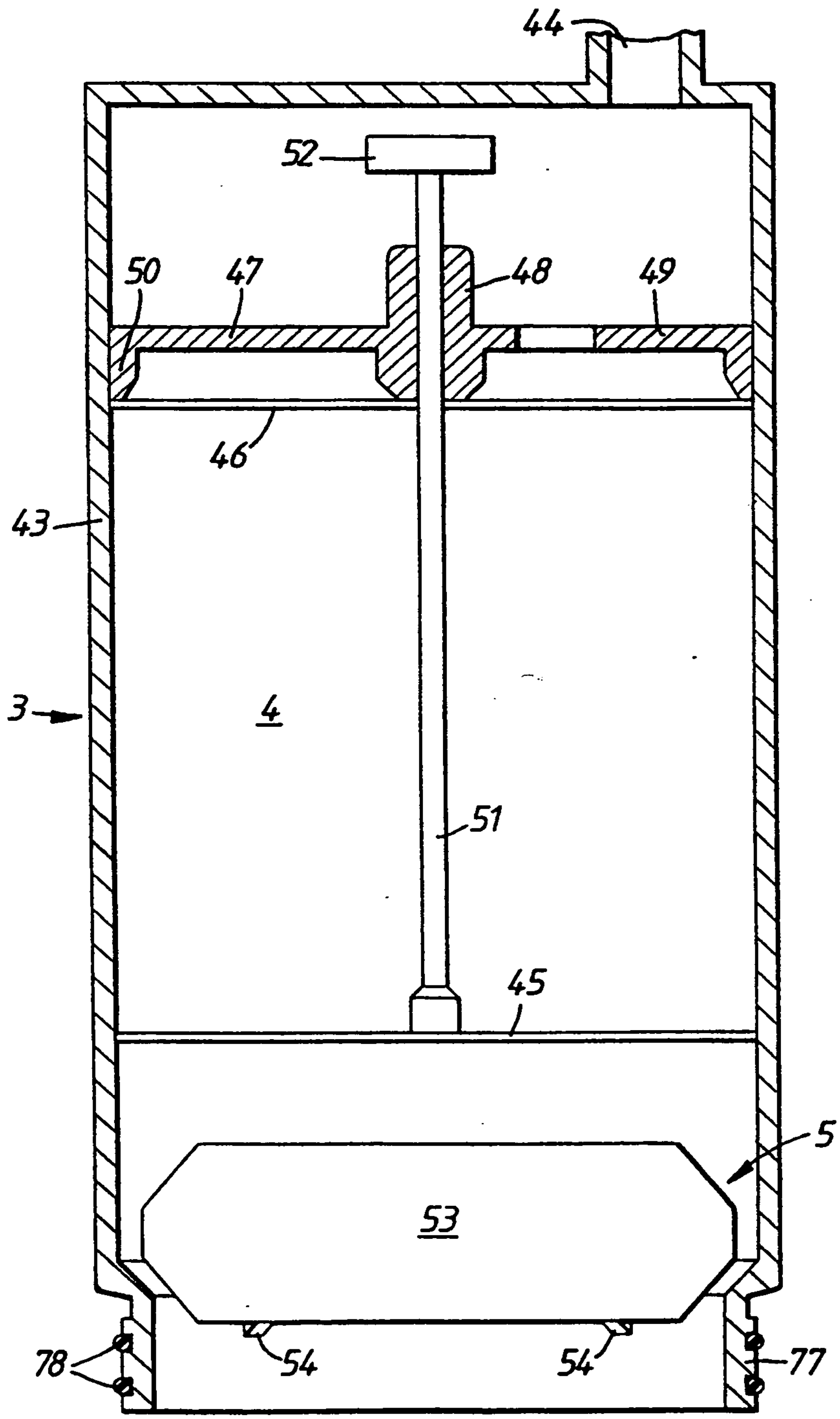

FIG. 3.

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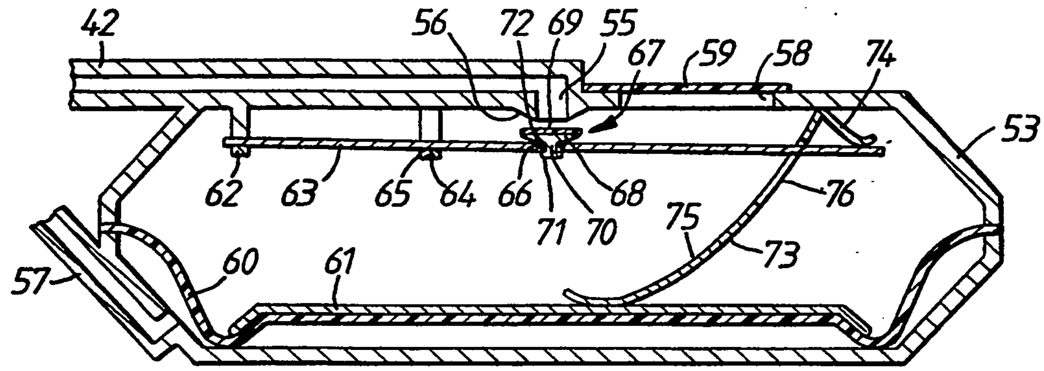

FIG.4.

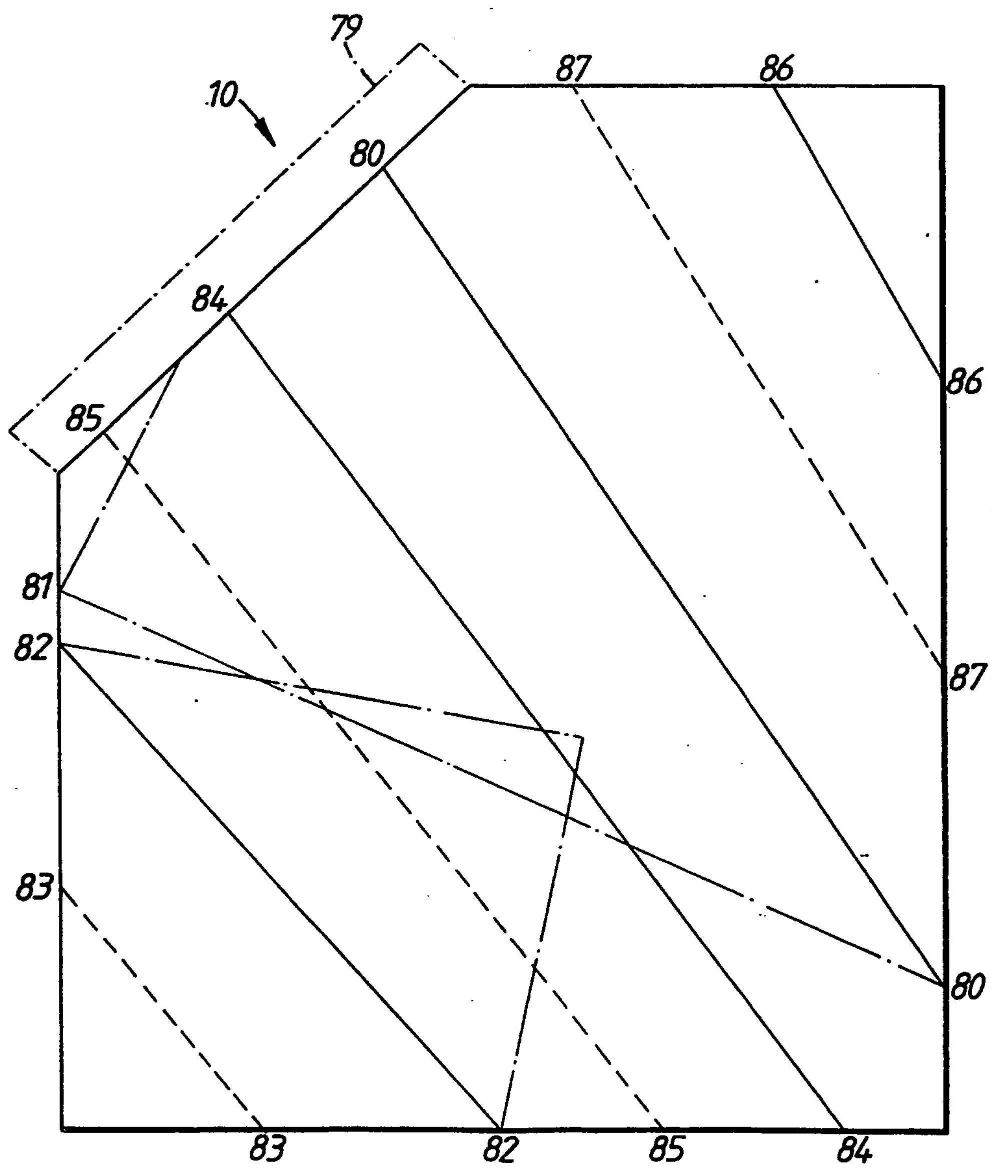

FIG.5.

SPECIFICATION

Improvements in and relating t breathing apparatus

The invention relates to breathing apparatus and components suitable for use in such apparatus, and especially to 'self-rescue' breathing apparatus (and components for such apparatus), that is to say, to breathing apparatus that is worn by, for example, a coal-miner, as part of his normal equipment but is used only in emergencies to enable the wearer to escape through regions that are flooded or are filled with toxic or suffocating gases. Such breathing apparatus does not need to have a very long operating endurance, but must be sufficiently light and, in its usual inoperative condition, compact, that it does not unduly hinder the wearer's work. Such breathing apparatus may include a reducing valve, a demand valve, and a breathing bag.

The invention provides a demand valve comprising an inlet, a valve member, an elongate resilient member supported at one end portion and carrying the valve member at a central portion opposite the inlet, and pressure-responsive means arranged to deflect the other end portion of the resilient member in a direction to move the valve member to open and/or close the inlet.

The elongate resilient member acts both as a spring biasing the valve and as a lever connecting the valve member and the pressure-responsive means.

The resilient member may be so arranged that in operation it holds the valve member in a position closing the inlet and the pressure-responsive means may then be arranged to deflect the resilient member to permit the valve to open.

The pressure-responsive means may comprise a diaphragm exposed on one side to the pressure downstream of the inlet and on the other side to a reference pressure, which is advantageously ambient pressure, and a lever arranged to be rotated by the diaphragm as the diaphragm moves and to deflect the resilient member as it rotates. The demand valve will then open only when the pressure downstream of the inlet is far enough below ambient pressure that the pressure difference across the diaphragm can overcome the resilient member. Preferably, however, the resilient member is set so that it only just maintains the valve closed against the maximum operating pressure in the inlet, so that the valve will begin to open at a low pressure difference across the diaphragm.

The elongate resilient member may be supported by clamping means at an extreme end portion and by a fulcrum member, which may be in the form of a crossbar supported on posts on either side of the resilient member, between the clamping means and the inlet and on the opposite side of the resilient member from the inlet, and when the valve member closes th inlet the resilient memb r preferably engag s th clamping means, the valve member, and the fulcrum member and is stressed thereby to exert pressure on the fulcrum member and the valve member. A substantial force can then be applied to the valve member without the clamping means being subjected to a large torque, because a couple can be produced by normal forces at the clamping means and the fulcrum member together.

The invention also provides a demand valve comprising an inlet having a valve seat, a valve member arranged to close the inlet, and a valve lever supporting the valve member, wherein the valve member has a spherically convex rear face that engages a corresponding formation on the valve lever and is adjusted by rotation to a preferred orientation for engaging the valve seat.

Usually, the valve seat and the portion of the valve member that engages it will each be planar, and if they are not parallel when they come into contact then a very large force may be necessary to effect a seal. Especially when, as is preferred, the valve lever is the elongate resilient member mentioned above, the possibility of adjusting the orientation of the valve member after the resilient member has been set to a desired stress greatly facilitates achieving reliable closing of the inlet with low actuating forces.

The said corresponding formation on the valve lever is advantageously the rim of a circular aperture in the valve lever.

The valve member may be left free to orientate itself every time the valve closes, but is preferably adhesively secured or otherwise bonded in the said preferred orientation relative to the valve lever once that orientation is found while assembling and adjusting the valve. The valve member may be secured to the valve lever by causing or permitting a silicone sealant compound to set around them.

The demand valve may be for use in breathing apparatus, advantageously for supplying oxygen in closed-circuit breathing apparatus, the inlet being in communication with a source of oxygen when the apparatus is in operation.

The invention also provides breathing apparatus comprising means for supplying oxygen or oxygen-containing gas and a demand valve according to the invention for delivering that gas from the supply to a user.

The invention further provides a pressure-reducing valve comprising a cylinder having a closed end, a piston slidably movable within the cylinder and in sealing engagement with the walls of the cylinder, an inlet for gas under pressure into the cylinder between the piston and the closed end, and a valve member attached to the piston, the arrangement being such that the pressure of the gas or other fluid in the inlet tends to urge the valve member in a direction away from the piston and thereby to increase the degree of opening of the inlet.

The opening of the inlet is thus governed by the gauge pressure in the cylinder (measured relative to the pressure on the outside of the piston). Because of the orientation and location of the inlet, only one fluid-tight sliding seal is needed, around the piston, instead of the two that are necessary in conventional piston-actuated pressure-reducing valves, with a consequent reduction in maintenance and increase in reliability.

Advantageously, a pipe for the gas under

pressure extends across th cylinder between the piston and the closed end, the inlet is a port in th wall of the pipe opening towards the clos d nd of the cylinder, and the valve member is connected to the piston by tie-rods straddling the pipe. The piston may be resiliently biased along the cylinder, advantageously by a compression spring acting on the outside of the piston, in order to give a desired pressure-response.

The invention also provides a pressure-reducing valve comprising a housing, a member movable within the housing, which member preferably is, or is operatively connected to, the piston or the valve member mentioned above, to open and close the valve and having a portion that projects outside the housing by an amount that depends on the degree of opening of the valve, and means engaging the projecting portion and arranged to hold the valve closed.

The projecting portion advantageously projects more when the valve is closed than when the valve is open, and the holding means then preferably comprises a lever having a first end portion engaging under a head on the projecting portion, a central portion engaging the housing as a fulcrum, and a seond end portion, and so arranged that the second end portion can be urged towards the valve housing to hold the valve closed.

The projecting portion of the movable member may be an extension of the piston out of the end of the cylinder opposite the said closed end.

When, as is preferred, the pressure-reducing valve is arranged for use as a cylinder-head valve, the holding means can be used to hold the valve closed when it is not in use and can be arranged to release the valve automatically when apparatus to which the valve is connected is brought into operation, thus avoiding the need for the maker to provide and the user to operate a conventional cylinder-head shut-off valve. The pressure-reducing valve may be arranged for use as the cylinder-head valve of an oxygen cylinder in closed-circuit breathing apparatus.

The invention further provides breathing apparatus comprising a pressure-reducing valve according to the invention.

Advantageously, the pressure-reducing valve comprises means as mentioned above arranged to hold the valve closed, and the breathing apparatus comprises a cover that is removed when the apparatus is brought into operation and that is arranged so to engage the holding means that the pressure-reducing valve is held closed while the cover member is in place.

The invention also provides a breathing bag for closed-circuit breathing apparatus, folded and rolled substantially as hereinafter described with reference to Fig. 5 of the accompanying drawings, which gives a roll that is extremely compact, having regard to the size of the bag and the properties of the mat rials from which such bags are made, and that readily opens out for use.

Th invention further provides breathing apparatus which includes a breathing bag according to the invention.

Th br athing bag, in the usual orientation of the apparatus, is preferably enclosed within a bottom cov r member that is remov d when the apparatus is brought into operation, and so constructed and arranged as to tend to fall and open out under its own weight to hang from the apparatus when the bottom cover member is removed. With a breathing bag folded and rolled according to the invention, that can readily be achieved provided that the breathing bag can fall free, and the opening out of the bag is completed when the user of the apparatus first exhales into the apparatus.

The invention also provides breathing apparatus comprising a unit with top and bottom cover members covering parts of the apparatus that are to be extended when the apparatus is brought into operation to occupy space outside the positions of the cover members, and members in tension extending from one cover member to the other, the cover members being so arranged that they are secured to the apparatus by virtue of being secured to each other by the members in tension, and at least one said member in tension being breakable by a wearer of the apparatus to enable the cover members to be removed.

The said at least one member in tension is advantageously a wire, and at least one other said member in tension is advantageously a mono-filament fibre. The cover members are preferably so arranged that when the wire is broken the tensile energy in the monofilament will tend to assist in dislodging the cover members from the apparatus. The top cover member may cover a facemask, mouthpiece, or the like and a flexible hose connecting it to the rest of the apparatus, and the bottom cover member may cover a breathing bag if the apparatus is closed-circuit breathing apparatus.

The invention further provides breathing apparatus comprising a waist-belt, a diagonal shoulder-belt attached thereto, and a unit slidably mounted on the diagonal belt holding the operative parts of the breathing apparatus and arranged to be worn at approximately waist-level on a bottom end portion of the diagonal belt when not in use and to be slid up onto the wearer's chest when it is brought into operation. If, as is preferred, the breathing apparatus incorporates some or all of the other aspects of the present invention mentioned above, then it is possible to construct a self-rescue breathing apparatus that is small enough to hang at the waist without seriously inconveniencing the wearer while still giving satisfactory performance when it is needed.

One form of breathing apparatus constructed in accordance with the invention will now be described by way of example only with reference to the accompanying drawings, in which:

Fig. 1 is a schematic view of the self-rescuer in an inoperative, ready-for-use, condition;

Fig. 2 is a cross-sectional view of a cylinder-head reducing valve, to a larger scale than Fig. 1;

Fig. 3 is a cross-sectional view of a purifier and ass mbly, to a larger scale than Fig. 1;

Fig. 4 is a cross-sectional view of a demand valve capsule, to a larger scale than Fig. 3; and

Fig. 5 is a diagram of a breathing bag.

Referring to the accompanying drawings, one form of closed-circuit breathing apparatus suitable for use as a self-rescue apparatus comprises an oxygen cylinder 1 with a cylinder-head valve assembly indicated generally by the reference numeral 2, a purifier indicated generally by the reference numeral 3 containing a granular material 4 that can remove carbon dioxide chemically from air, and a demand valve indicated generally by the reference numeral 5 that in operation releases, into the gas being breathed by a user of the apparatus, oxygen supplied to it from the oxygen cylinder 1 by the cylinder-head valve 2.

As may be seen from Fig. 1, the oxygen cylinder 1 with the cylinder-head valve 2 on top of it, and the purifier 3 with the demand valve 5 under it, form two generally cylindrical modules secured side-by-side and in use carried by a wearer by means of a harness that comprises a diagonal shoulder-belt 6, to which the self-rescuer is slidably attached, and a waist-belt 7.

In the inoperative configuration shown in Fig. 1, a top cap 8 is secured on top of the purifier 3, and a nose-clip and mouthpiece, with a flexible hose connecting the mouthpiece to the purifier, are stored under the top cap. The nose-clip, mouthpiece, and hose may be of conventional design, and in the interests of clarity have been omitted from Fig. 1.

Similarly, a bottom cap 9 is secured under the demand valve 5 and contains within it a breathing bag 10 which in the interests of clarity has been omitted from Fig. 1. The top cap 8 and the bottom cap 9 are connected together by a wire (not shown) on one side of the purifier 3 and a monofilament fibre (not shown) on the other side of the purifier. Both the wire and the nylon strand are in tensimn, and serve to hold the top and bottom caps 8 and 9 in position seated on the purifier module. The rims of the caps 8 and 9, and the surfaces of the module which they abut, may be configured to provide reliable seating of the caps under the tension in the wire and the fibre. The wire is sufficiently thin to be easily broken by a wearer of the self-rescuer, and the caps 8 and 9 are so arranged that if the wire is broken they readily become detached from the rest of the apparatus, assisted by the tension in the monofilament fibre. A handle may be provided to assist the wearer in breaking the wire.

Referring now to Fig. 2, the cylinder-head valve 2 comprises a high-pressure tube 11 a lower end portion of which is secured within and sealed to the mouth of the oxygen cylinder 1 by appropriate means which may be conventional and typically include a screw-threaded connection. Within the lower end portion of the high-pressure tube 11 is an upper end portion of an anti-rust tube 12. The anti-rust tube 12 is a p rforated tube that extends down into the oxygen cylinder 1 and permits oxygen from the cylinder to enter the high-pressure tube 11 while sieving out flakes of rust and other coarse debris that may be present in the cylinder.

Th upp r end of the anti-rust tube 12 is closed off by a porous sintered copper disc 13 that filters out finer debris. In an upper portion of the high-pressure tube 11 there is a constriction 14 defined by an annular flange 15 the underside of which forms a smooth frustoconical surface. Below the flange 15 is a spherical ball 16, smaller than the unconstricted internal diameter of the high-pressure tube 11 but larger than the diameter at the constriction 14 and urged upwards by a spring 17. Above the constriction 14 is another porous sintered copper filter 18, and above that the top end of the high-pressure tube 11 is closed off by a screw-plug 19 sealed by an O-ring 20.

The high-pressure tube 11 passes diametrally across a horizontal cylinder 21 the internal diameter of which is about twice the external diameter of the high-pressure tube. The walls of the cylinder 21 are welded to the high-pressure tube 11 to give structural strength and to ensure that the cylinder does not leak around the tube. A port 22 opens out through the wall of the high pressure tube 11 along the axis of the cylinder 21, to the left as shown in Fig. 2. The outer end of the port 22 is surrounded by a raised rim 23 forming a valve seat. The left-hand end of the cylinder 21 is closed.

The valve seat 23 is faced by a valve member indicated generally by the reference numeral 24, which comprises a resilient pad 25 in a holder 26 carried by a support plate 27. The support plat 27 is in a plane perpendicular to the axis of the cylinder 21 and spans most of the diameter of the cylinder, but is not sealed to the walls of the cylinder, and may be apertured to ensure a free flow of gas from one side of the plate to the other. The holder 26 is a member screwed into a threaded hole in a bush 28 in the centre of the support plate 27 ~~and holding~~ the resilient pad 25 in a recess in its right-hand (as seen in Fig. 2) end. The axial position of the resilient pad 25 relative to the support plate 27 can be adjusted by screwing the holder 26 in or out, and the back end of the holder 26 is provided with a slot for a screw-driver. An aperture with a screw-plug 29 of other removable closure may be provided in the closed end of the the cylinder 21 in order that the holder 26 may be adjusted after the valve 2 has been assembled.

On the other side of the high-pressure tube 11 (the right-hand side as seen in Fig. 2) there is a piston indicated generally by the reference numeral 30 in the cylinder 21. The piston 30 comprises a piston-head 31 that is sealed to the walls of the cylinder 21 by an O-ring 32. The piston-head 31 is rigidly connected to the support plate 27 by at least two tie-rods 33 (four as shown in Fig. 2) straddling the high-pressure tube 11.

The right-hand end of the cylinder 21 is closed by an end-plate 34 with a central aperture through which passes a piston-rod 35 of the piston 30. The piston rod 35 is s aled to the nd-plate 34 by an O-ring 36. The end portion of the piston rod 35 outside the end-plate 34 has an annular groove defining a head 37 connected to the main part of the piston rod by a neck 38. A forked end portion of a lev r 39 engages the h ad 37 on either side of the neck 38. A curved portion of the lever 39 engages the nd plate 34 as a fulcrum, beyond which the lever extends

upwards and to the right as shown in Fig. 2. As is shown in Fig. 1, the lever 39 is so positioned that when the top cap 8 is in place a side face of the top cap holds the upper arm of the l ver to the left. That causes the lower, forked, end portion of the lever to hold the head 37 of the piston rod 35 to the right and, through the piston rod, the piston head 31, and the tie-rods 33, holds the valve member 24 to the right. The holder 26 is so adjusted in the support plate 27 that with the top cap 8 in place the resilient pad 25 of the valve member 24 is pressed against the valve seating 23 and completely seals off the port 22.

A stack of frusto-conical washers 40 forms a compression spring acting between the piston head 31 and the end plate 34 of the cylinder 21.

A relief valve 41 (not shown in detail) permits any excess of pressure in the region between the piston head 31 and the end plate 34 to escape to the exterior.

An oxygen pipe 42 communicates with the region between the piston head 31 and the closed (left-hand) end of the cylinder 21.

Referring now to Fig. 3 of the drawings, the purifier 3 comprises a cylindrical housing 43 closed at the top, with a connector 44 for the hose connected to the mouthpiece opening through the top wall. A perforated plate 45, which may be a rigid gauze, is mounted across the housing 43 near the bottom, and the carbon dioxide absorbing material 4 is on top of the perforated plate. On top of the material 4 is a second perforated plate 46, on which rests a piston 47. The piston 47 comprises a central bushing 48, an apertured disc 49, and a downwardly-extending peripheral skirt 50. The bottom ends of the bushing 48 and of the skirt 50 rest on the upper perforated plate 46. A tie bar 51 is secured at its lower end to the lower perforated plate 45, passes up through an aperture in the upper perforated plate 46, and through the bushing 48, and terminates in an enlarged head portion 52. A coil spring 53 acts in compression between the bushing 48 of the piston 47 and the head 52 of the tie bar 51, and thus urges the two perforated plates 45 and 46 towards one another and maintains the granular material 4 in a compact condition under compression.

The demand valve 5 comprises a capsule 53 that is supported on four radially spaced-apart brackets 54 within a bottom end portion of the housing 43, the regions above and below it being in communication between the brackets.

Referring now to Fig. 4, the oxygen pipe 42 passes through the housing 43 and is in communication with the interior of the demand-valve capsule 53 through a part 55 in the centre of the top of the capsule. The port 55 is surrounded by a raised rim 56 that forms a valv seat. A pipe 57 that is in communication with the ambient atmosphere at one end passes through the housing 43 and opens out into the demand-valv capsul 53 through a lower wall. The interior of the capsule 53 is in communication thr ugh a larg opening 58 in its top with the region within the housing 43 below the lower perforated plate 45. The large opening 58 in the top of the capsule 53 is cov red by a flap valve 59 that prevents any particles that may fall from the purifier material 4 from entering the valve capsule 53.

Within the demand-valve capsule 53 is a flexible diaphragm 60 with a central stiffening plate 61. The diaphragm 60 is secured to the walls of the capsule 53 round the sides thereof above the level of the opening from the ambient atmosphere inlet pipe 57, and is so arranged that it can lie substantially limp against the walls of the lower part of the capsule.

A post 62 projects downwardly from the top wall of the demand-valve capsule 53 near the periphery threof. To the post 62 is secured a lever-blade 63 of resilient material that extends generally horizontally across the middle of the top wall of the capsule, and across the oxygen port 55. Between the oxygen port 55 and the post 62 are a pair of further posts 64, one on each side of the blade 63, between which a crossbar 65 extends under the blade. The crossbar 65 is of inverse U or V shaped cross-section, with the blade 63 resting on its central convexity. The height of the post 62, or of the further posts 64, or both, may be adjustable to adjust the stress in the blade 63. Opposite the oxygen port 55 is a circular hole 66 in the blade 63, on the rim of which rests a valve member indicated generally by the reference numeral 67. The valve member 67 comprises a body 68 in the form of a minor segment of a sphere, the upper, flat, face of which is covered by a resilient pad 69 and the lower, convex, face of which rests on the rim of the hole 66. From the centre of the convex face of the body 68 projects a short stalk 70 on the end of which is a flat head 71 that is of slightly smaller diameter than the hole 66. When the demand valve 5 is assembled, the blade 63 and the valve member 67 are adjusted so that the resilient pad 69 seats flat against the valve seat 56 and the blade 63 exerts just sufficient force on the valve member to keep the valve closed against gravity and against the operating pressure in the oxygen tube 42. A silicone material 72 is then introduced between the head 71 of the valve member 67 and the blade 63 and allowed to set. Because of the convexity of the lower face of the body 68, the valve member is to some extent self-aligning, which facilitates the initial adjustment of the valve, but the silicone material 72 removes the risk that the valve member will become displaced in operation and the valve will fail to function correctly.

An asymmetrical V-shaped lever 73 rests with its angle against the underside of the top wall of the demand valve capsule 53 as a fulcrum, with a short arm 74 engaging the free end of the blade 63, and with a long arm 75 engaging the stiffening plate 61 of the diaphragm 60. The lever 73 may be held in place, if necessary, by any appropriate means. Because the lever 73 and the blade 63 lie, and must in operation move, in the same plane, th long arm 75 of the lever is broader than the blade and has near the fulcrum an apertur 76 through which the blade pass s. As may be seen from Fig. 4, if the diaphragm 60 rises it rotates the lever 73 in such a sense (clockwise as seen in Fig. 4) that the short arm 74 of the lever urges the free end of the blade 63

downwards, lowering the valve member 67 away from the oxygen port 55 and opening the valve. Because the blade 63 flexes along its l ngth, instead of pivoting about either the post 62 or the crossbar 65, a comparatively large movement of the free end of the blade is needed to operate the valve, and that is provided by the shape of the lever 73 and by the length of travel of the centre of the diaphragm 60.

The bottom half of the demand valve capsule 53 may be made removable to afford access to the demand valve mechanism.

Referring again to Fig. 3, the extreme bottom end portion of the housing 43, below the demand valve 5, is formed as a connector 77, with O-rings 78 or other appropriate sealing means, for the mouth of the breathing bag 10. Because the breathing bag 10 and the demand valve 5, which are the two parts of the apparatus most sensitive to the ambient pressure, are so close together, the effect of a difference in pressure between them, which could be appreciable under water and would depend on the wearer's attitude, is minimized.

Referring now to Fig. 5, the breathing bag 10 in an empty, relaxed, condition is generally rectangular and consists of two flat sheets welded or otherwise bonded together around the edges, with a mouth member 79 (not shown in detail) that engages with the connector 77 in the top left-hand corner as seen in Fig. 5. Each sheet may consist of a laminated plastics material impervious to air. The mouth member 79 may cut off the corner of the bag 10, as shown in dotted lines in Fig. 5. In order to pack the breathing bag, which when flat may be about 40 cm × 30 cm, in as small a space as possible, the top right hand (as seen in Fig. 5) portion is folded upwards along the line 80—80, so that the top right hand corner comes to lie about half-way down the left hand side at the point marked 81, as shown in chain-dotted lines. Then the bottom left-hand portion is folded upwards along the line 82—82 and comes to lie approximately alongside the top right-hand portion, as shown in chain-dotted lines. The two folded portions do not lie quite parallel because the folding lines diverge somewhat towards the top left. The bottom left portion is then folded back at the line 83—83. The left-hand portion of the resulting strip is then folded over to the right along the line 84—84 and back along the line 85—85. The result is a compact strip with the entire long diagonal from top left to bottom right, and the mouth member 79, on the bottom ply and shorter and shorter plies, culminating in the top right-hand and bottom left-hand corners, on top. If the bag is then unfolded, it will be found to have creases forming valleys at the locations of the solid lines 80—80, 82—82, 84—84, and 86—86 and ridges at the locations of the dashed lines 83—83, 85—85, and 87—87. If, however, the folded strip is rolled up, beginning at the bottom right, it forms a roll that is exceptionally compact for the size of the bag 10, with the mouth member 79 at the outermost point. If the mouth m mber 79 of the breathing bag 10 is opened out and fast ned ov r the connector 77, it is still possible to fold and roll most of the bag and to store the roll within the connector.

In order to prepare the apparatus for use, the oxygen cylinder 2 may be charged by removing the screw plug 19 and, with the valve 23 and 24 closed, injecting oxygen under pressure through the orifice 14. The ball 16 then acts as a non-return valve, seating against the flange 15, preventing the oxygen from escaping once the supply of oxygen has been removed until the screw-plug 19 is replaced. Because the ball 16 only acts as the principal valve for a short period, it does not need to provide a totally leak-tight seal and a more elaborate seating for it is unnecessary. Once the oxygen cylind r is charged up, the reducing valve 23 and 24, which also acts as a cylinder-head valve, should preferably be kept shut at all times until the apparatus is required for use although, since the demand valve 5 is a negative-pressure valve, it will in practice provide a second line of defence. As has been indicated above, once the top cap 8 is in place the lever 39 automatically holds the reducing valve 23 and 24 shut.

Because the oxygen cylinder 1 can be recharged without removing it from the apparatus or removing the cylinder-head valve 2 from the cylinder, the cylinder-head pressure-reducing valve 2 and the demand valve 5 always operate together as a pair, so that to some extent each can compensate for variations from nominal performance in the other. In conventional apparatus in which the cylinder and cylinder-head valve are exchanged during routine maintenance, that could not be done without re-adjusting the valves every time the cylinder was exchanged.

The charge of carbon dioxide absorbing material 4 in the purifier 3 may be renewed in any convenient way, for example, the top wall of the housing 43 and the tie bar 51 may be removable.

The breathing bag is rolled up as has been described, and stowed inside the bottom end cap 9.

The apparatus is worn by the user at the bottom of the diagonal belt 6 of the harness, and thus hangs at about waist level and somewhat to one side, where it is not as likely to be in the wearer's way, and is not as likely to be damaged, as if it were worn permanently on the wearer's chest.

When he needs to use the apparatus, the wearer slides it up the shoulder belt 6 until it is in th centre of his chest, breaks the wire connecting the top and bottom end caps 8 and 9, and removes the end caps. He then exhales, and puts on the nose-clip and mouthpiece, and begins to breathe using the apparatus.

The removal of the top end cap 8 releases the lever 39, freeing the cylinder-head reducing-valve 23 and 24. The wearer does not have to manipulate a manual cylinder-head valve. As may be seen from Fig. 2, the vorces acting on the moving assembly within the valve are: the oxygen-cylinder pressure, acting on the area of the port 22 and becoming less effective as the valv opens; the pressur in the closed end of the cylinder 21, acting on the area of the piston head 31; and the force of the stack of washers 40.

Because the area of the port 22 is much smaller than that of the piston head 31, the reducing valve

will supply oxygen at a pressure determined primarily by the stack of washers 40, which can be set with some accuracy. The reducing valve might be set to supply oxygen at, for example, 750 kPa with a full oxygen cylinder, th pressure falling by, for example, 10% as the cylinder empties. The travel of the piston 30 and the valve member 24 is limited by the piston head's coming into contact with the high-pressure tube 11 while the stack of washers 40 is still under compression.

The volume to the right of the piston head 31 as seen in Fig. 2 is sealed from the exterior to protect the piston head O-ring 32 and the washers 40 against the water, mud, and the like to which a self-rescue apparatus may be exposed in operation. Because of slight leakages around the valve pad 25 and the O-ring 32, that volume will in practice usually contain oxygen at slightly above ambient pressure, any significant excess pressure being relieved by the relief valve 41.

When the wearer of the apparatus exhales, his exhaled breath will pass from the mouthpiece, through the flexible hose, into the housing 43. The breath will then pass through the apertures in the disc 49 of the piston 47, spread out in the space between the apertured disc and the upper perforated plate 46, which space acts as a plenum, pass down through the granular purifying material 4, round the demand valve capsule 53, and into the breathing bag 10.

Because the operating characteristics of the reducing-valve 2 are determined largely by the dimensions of the valve mechanism and by the stack of washers 40, which can be made to very precise tolerances, the reducing valve can be made with sufficiently uniform and reliable performance that it needs no further adjustment in the field.

When the wearer inhales, the gas from the breathing bag 10 will follow the same path in reverse, passing round the demand valve 5 and up through the purifier 3. If the wearer inhales as deeply as he exhaled, and if the purifying material 4 has absorbed any appreciable amount of carbon dioxide, then the breathing bag may be emptied before the wearer has finished inhaling and the pressure within the apparatus will start to fall. The Diaphragm 60 in the demand valve 5 is exposed on its upper side to the pressure within the apparatus, through the large opening 58 and on its underside to ambient pressure through the pipe 57. If the pressure within the apparatus falls far enough below ambient pressure, therefore, the ambient pressure will lift the diaphragm 60, which will turn the lever 73 and urge the free end of the blade 63 downwards. If the movement is sufficient, the demand valve member 67 will be lowered off its seat 56, permitting oxygen from the oxygen pipe 42, that is to say, from the cylinder-head reducing-valve 2, to enter the capsule 53 and thence the housing 43 and the lungs of the wearer until the volume of breathing gas in the apparatus is made up.

It will be seen that there is no oxygen bleed by-passing the demand valve 56 and 67. Oxygen is supplied only on demand, at negative gaug pressure, and the apparatus relies on the integrity of its seals to pr vent the ambient atmosphere (which may b , for example, muddy water) from entering th apparatus. That has, however, the advantage that no oxygen is wasted and thus the endurance of the apparatus is increased.

When the bottom end-cap 9 is removed, the breathing bag 10 falls and unrolls, at least partly, under its own weight. When the wearer first exhales into the breathing bag, the gas pressure unfolds and expands the breathing bag, which then hangs freely from the connector 77.

CLAIMS

1. A demand valve comprising an inlet, a valve member, an elongate resilient member supported at one end portion and carrying the valve member at a central portion opposite the inlet, and pressure-responsive means arranged to deflect the other end portion of the resilient member in a direction to move the valve member to open and/or close the inlet.

2. A demand valve as claimed in claim 1, wherein the resilient member is so arranged that in operation the resilient member holds the valve member in a position closing the inlet and the pressure-responsive means is arranged to deflect the resilient member to permit the valve to open.

3. A demand valve as claimed in claim 1 or claim 2, wherein the pressure-responsive means comprises a diaphragm exposed on one side to the pressure downstream of the inlet and on the other side to a reference pressure, and a lever arranged to be rotated by the diaphragm as the diaphragm moves and to deflect the resilient member as it rotates.

4. A demand valve as claimed in claim 3, wherein the reference pressure is ambient pressure.

5. A demand valve as claimed in any one of claims 1 to 4, wherein the resilient member is suported by clamping means at an extreme end portion and by fulcrum member intermediate between the clamping means and the inlet and on the opposite side of the resilient member from the inlet, and wherein when the valve member closes the inlet the resilient member engages the clamping means, the valve member, and the fulcrum member and is stressed thereby to exert pressure on the fulcrum member and the valve member.

6. A demand valve comprising an inlet having a valve seat, a valve member arranged to close the inlet, and a valve lever supporting the valve member, wherein the valve member has a spherically convex rear face that engages a corresponding formation on the valve lever and is adjusted by rotation to a preferred orientation for engaging the valve seat.

7. A demand valve as claimed in claim 6, wherein the said corresponding formation is the rim of a circular ap rture in the valve lever.

8. A demand valve as claimed in claim 6 or claim 7, wherein the valve member is adhesively secured in the said pr ferred ori ntation relative to the valve lever.

9. A demand valve as claimed in claim 8, wherein the valve member is secured to the valve lever by

causing or permitting a silicone compound to set around them.

10. A demand valve as claimed both in any one of claims 1 to 5 and in any one of claims 6 to 9, wher in the said elongate resilient member is the said valve lever.

11. A demand valve as claimed in any one of claims 1 to 10 for use in breathing apparatus.

12. A demand valve as claimed in claim 11 for supplying oxygen in closed-circuit breathing apparatus, the inlet being in communication with a source of oxygen when the apparatus is in operation.

13. A demand valve substantially as hereinbefore described with reference to, and as shown in Fig. 3 of, the accompanying drawings.

14. Breathing apparatus comprising means for supplying oxygen or oxygen-containing gas and a demand valve as claimed in any one of claims 1 to 13 for delivering that gas from the supply to a user.

15. A pressure-reducing valve comprising a cylinder having a closed end, a piston slidably movable within the cylinder and in sealing engagement with the walls of the cylinder, an inlet for gas under pressure into the cylinder between the piston and the closed end, and a valve member attached to the piston, the arrangement being such that the pressure of the gas in the inlet tends to urge the valve member in a direction away from the piston and thereby to increase the degree of opening of the inlet.

16. A pressure-reducing valve as claimed in claim 15, wherein a pipe for the gas under pressure extends across the cylinder between the piston and the closed end, the inlet is a port in the wall of the pipe opening towards the closed end of the cylinder, and the valve member is connected to the piston by tie-rods straddling the pipe.

17. A pressure-reducing valve as claimed in claim 15 or claim 16, wherein the piston is resiliently biased along the cylinder.

18. A pressure-reducing valve comprising a housing, a member movable within the housing to open and close the valve and having a portion that projects outside the housing by an amount that depends on the degree of opening of the valve, and means engaging the projecting portion and arranged to hold the valve closed.

19. A pressure-reducing valve as claimed in claim 18, wherein the projecting portion projects more when the valve is closed than when the valve is open.

20. A pressure-reducing valve as claimed in claim 19, wherein the holding means comprises a lever having a first end portion engaging under a head on the projecting portion, a central portion engaging the housing as a fulcrum, and a second end portion, and so arranged that the second end portion can be urged towards the valve housing to hold the valve closed.

21. A pressure-reducing valve as claimed both in any one of claims 15 to 17 and in any one of claims 18 to 20, wherein the movable member is, or is operatively connected to, the piston or the valve member.

22. A pressure-reducing valv as claimed in claim 21, wherein th projecting portion of the movable member is an extension of the piston out of the end of the cylinder opposite the said closed nd.

23. A pressure-reducing valve as claimed in any one of claims 15 to 22, for use as a cylinder-head valve.

24. A pressure-reducing valve as claimed in claim 23, for use as the cylinder-head valve of an oxygen cylinder in closed-circuit breathing apparatus.

25. A pressure-reducing valve substantially as hereinbefore described with reference to, and as shown in Fig. 2 of, the accompanying drawings.

26. Breathing apparatus comprising a pressure-reducing valve as claimed in any one of claims 15 to 25.

27. Breathing apparatus as claimed in claim 26, wherein the pressure-reducing valve is as claimed in any one of claims 18 to 22, or in claim 23 or claim 24 when dependent upon any one of claims 18 to 22, or in claim 25, which comprises a cover that is removed when the apparatus is brought into operation and that is arranged so to engage th holding means that the pressure-reducing valve is held closed while the cover member is in place.

28. Breathing apparatus as claimed both in claim 14 and in claim 26 or claim 27.

29. A breathing bag for closed-circuit breathing apparatus, folded and rolled substantially as hereinbefore described with reference to Fig. 5 of the accompanying drawings.

30. Breathing apparatus that includes a breathing bag as claimed in claim 29.

31. Breathing apparatus as claimed in claim 30, wherein the breathing bag, in the usual orientation of the apparatus, is enclosed within a bottom cover member that is removed when the apparatus is brought into operation, and the breathing bag is so constructed and arranged as to tend to fall and open out under its own weight to hang from the apparatus when the bottom cover member is removed.

32. Breathing apparatus as claimed both in claim 30 or claim 31 and in any one of claims 14 and 26 to 28.

33. Breathing apparatus comprising a waist-belt, a diagonal shoulder-belt attached thereto, and a unit slidably mounted on the diagonal belt holding the operative parts of the breathing apparatus and arranged to be worn at approximately waist-level on a bottom end portion of the diagonal belt when not in use and to be slid up onto the wearer's chest when it is brought into operation.

34. Breathing apparatus as claimed both in claim 33 and in any one of claims 14, 26 to 28, and 30 to 32.

35. Breathing apparatus comprising a unit with top and bottom cover members covering parts of the apparatus that are extended wh n the apparatus is brought into operation, and members in tension extending from on cover member to the other, the cover members b ing so arranged that they are secured to the apparatus by virtue of being secured to each other by the members in tension, and at least one said member in tension being breakable by a wearer of the apparatus to enable the cover

members to be removed.

36. Breathing apparatus as claimed in claim 35 wherein the said at least one member in tension is a wire.

37. Breathing apparatus as claimed in claim 35 or claim 36, wherein at least one other said member in tension is a mon-filament fibre.

38. Breathing apparatus as claimed in any one of claims 35 to 37, wherein the top cover member covers a facemask, mouthpiece, or the like and a flexible hose connecting it to the rest of the apparatus, and the bottom cover-member covers a breathing bag.

39. Breathing apparatus as claimed both in any one of claims 35 to 38 and in any one of claims 14, 26 to 28, and 30 to 34.

40. Breathing apparatus substantially as hereinbefore described with reference to, and as shown in, the accompanying drawings.

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